FINAL TECHNICAL REPORT (N00014-99-1-0716)

Title: ACQUISITION OF MOLECULAR BEAM EPITAXY SYSTEM FOR FABRICATION OF HYBRID MAGNETIC/SEMICONDUCTOR HETEROSTRUCTURES

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Long term goals:
The long term goal is to develop a basis for a semiconductor "spintronics" technology that could enable integrable spin-dependent electronics and high density storage.

Objectives:
The specific objective of this project was to set up a molecular beam epitaxy for carrying out fabrication of complex hybrid heterostructures involving II-VI, III-V semiconductors, derivative magnetic semiconductors and metallic ferromagnets.

Approach:
An EPI 930 MBE system was purchased. The system was delivered in February 2000 and was fully installed and commissioned by March 2000. The new MBE system is currently set up for growth of GaAs, GaAlAs and GaMnAs and is fully integrated with a prior II-VI MBE chamber. The first set of materials grown include hetero- and nano-structures built from ferromagnetic metals (e.g. MnAs), paramagnetic II-Mn-VI semiconductors and ferromagnetic (Ga,Mn)As.

Work Completed:
1. *Molecular Beam Epitaxy of MnAs/ZnSe Hybrid Ferromagnet/Semiconductor Heterostructures.*
This is the first experimental work to integrate ferromagnetic MnAs with the II-VI semiconductor ZnSe. Unlike earlier work involving MnAs/semiconductor heterostructures, MnAs/ZnSe heterostructures can be grown at mutually compatible substrate temperatures (around 300 C). The MnAs/ZnSe heterostructures have a Curie temperature of 320K and ferromagnetic characteristics comparable to MnAs/GaAs heterostructures. Unlike the growth of MnAs/GaAs, here we find that only the type-B orientation of MnAs occurs. A detailed study of the properties of these heterostructures and their dependence on growth conditions has been reported. This work was accepted as an Applied Physics Letter and will appear in the Nov. 27, 2000 issue of the journal. An additional manuscript has been submitted to the proceedings of the North American MBE conference.

2. *Molecular Beam Epitaxy of GaMnAs and related heterostructures.*
We have successfully carried out the growth of (Ga,Mn)As alloys with Curie temperatures as high as 110K. The growth of alloys with Curie temperature between 50 – 80 K is now being routinely carried out. We have also carried out the first experimental work to integrate ferromagnetic (Ga,Mn)As with ZnSe for experiments that will examine spin injection into the non-magnetic semiconductor. In addition, we have begun experiments involving trilayers of MnAs/GaAs/(Ga,Mn)As to search for spin-dependent tunneling.

Publications:
1. J. J. Berry, S. H. Chun, K. C. Ku, N. Samarth, I. Malajovich, and D. D. Awschalom, "Molecular Beam Epitaxy of MnAs/ZnSe Ferromagnet/Semiconductor Hybrid Heterostructures," Applied Physics Letters (in press, Nov. 27, 2000).
2. S. H. Chun, J. J. Berry, K. C. Ku, N. Samarth, I. Malajovich, and D. D. Awschalom, "Growth and Characterization of MnAs/ZnSe Ferromagnet/Semiconductor Hybrid Heterostructures," Journal of Vacuum Science and Technology B **18** (submitted, October 2000).

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This instrumentation acquisition grant was used to purchase a molecular beam epitaxy system for growth of hybrid magnetic/semiconductor heterostructures. The system was delivered in February 2000, and has been fully commisioned. Two publications describing the growth of hybrid ferromagnet/semiconductor heterostructures have already resulted from this equipment (an Applied Physics Letter (11/27/00 issue) and a submitted conference paper that is undergoing review.) Several conference abstracts have been submitted based on work carried out in the new MBE system, including two invited talks at the PCSI and MMM/Intermag conferences in January 2000.

15. SUBJECT TERMS

Molecular beam epitaxy, heterostructures, semiconductor, ferromagnet

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